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“The small photovoltaic installation for a self-sustaining house”

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RESUMEN PROYECTO

En el proyecto adjunto a continuación, “The small photovoltaic installation for a self-sustaining house”, se describe la puesta en marcha de una instalación fotovoltaica para una vivienda familiar de cuatro personas totalmente aislada de la red eléctrica.

Dicho documento se estructura de la siguiente forma:

-Una breve introducción que aborda la necesidad de tener en cuenta las energías renovables tras conocerse que las fuentes convencionales de obtención de energía eran agotables, así como el gran abanico de posibilidades que tiene España en la extracción de energía solar y su crecimiento en los últimos años.

-Descripción de la energía solar y los tipos de radiaciones solares, seguido del movimiento e inclinación de la tierra con respecto al sol.

-Tecnología fotovoltaica, funcionamiento de la unión P-N para la extracción de energía, el circuito equivalente de una célula fotovoltaica y explicación de los puntos de trabajo de tensión y corriente para un funcionamiento óptimo.

-Explicación de los tipos de conexión de una instalación fotovoltaica, conectada a la red (ON-GRID) y aislada de ella (OFF-GRID).

-Análisis de los componentes necesarios para una instalación fotovoltaica aislada de la red: paneles solares, baterías, inversores, rectificadores y reguladores de carga, a la vez que los sistemas de seguimiento del sol.

-Tipos de células fotovoltaicas, materiales que las conforman, rendimientos y métodos de extracción, así como la evolución histórica de estas y su futuro desarrollo.

-Información adicional, protección de la instalación, reciclaje de los paneles tras cumplir la vida útil, mantenimiento y sistemas de monitorización.

-Análisis de un proyecto real en el sur de España, se estima el consumo de una vivienda para cuatro personas y con la ayuda del PVGIS, (Photovoltaic Geographical Information System), obtenemos la radiación solar incidente en la ubicación del proyecto y el ángulo óptimo de inclinación de los paneles a lo largo del año.

-Se procede a realizar los cálculos necesarios para la instalación, número de paneles y potencia, características de la batería y el inversor y coste del resto de aparatos.

-Por último introducimos nuestros datos en el programa de apoyo Retscreen* International para simular la viabilidad del proyecto y obtener una estimación de la recuperación de la inversión.

SUMMARY OF THE PROJECT

In the attached project, "The small photovoltaic installation for a self-sustaining house", the launch of a photovoltaic system fully isolated from the power supply, for a family home for four people is described.

This document is structured as follows:

-A brief introduction that suggests the need to consider renewable energies, after learning that conventional sources of energy production were exhaustible, as well as the wide range of possibilities for Spain in the extraction of solar energy and its growth in recent years.

-Description of solar energy and solar radiation types, followed by the movement and tilt of the earth respect to the sun.

-Photovoltaic technology, operation of the P-N junction for energy extraction, the equivalent circuit of a photovoltaic cell and explanation of the operating points of voltage and current for the optimal performance.

-Explanation of the types of connection of a photovoltaic system, connected to the network (ON-GRID) and isolated from it (OFF-GRID).

-Analysis of the components required for a photovoltaic installation isolated from the network: solar panels, batteries, inverters, rectifiers and charge controllers; also the sun tracking systems.

-Types of photovoltaic cells, materials that shape, yields and extraction methods, as well as the historical evolution and future development of them.

-Additional information, protection systems, recycling of the panels after the useful life, maintenance and monitoring systems.

-Analysis of a real project in the south of Spain, consumption of a home for four people is estimated and with the help of the PVGIS (Photovoltaic Geographical Information System), it is obtained the solar incident radiation on the project location and the optimum angle of inclination of the panels during the year.

-The calculations required for the installation are performed, also the equipment characteristics are specified and the cost of the devices.

-Finally it is introduced the data on the support program RETScreen * International, to simulate the feasibility of the project and obtain an estimation of the payback of the investment over the years.

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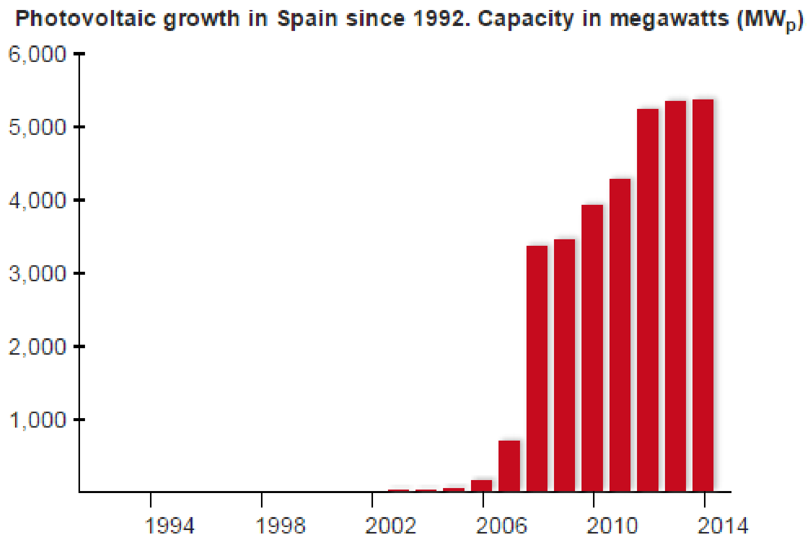
1. Introduction

Once the world realized that the most common fuels such as petrol and gas were exhaustible, appears the need to focus on different alternatives to get energy in order to minimize the use of this mentioned fuels and to decrease the energetic dependency with other countries. This is how the renewable energies became one of the most important sectors in the energy market.

The energy dependency of Spain has always been very high in comparison with other countries due to not having deposits of petrol and gas, because of this, in the last years it has been one of the countries that has invested more in renewable energies.

Spain has a very good location which provides plenty hours of sun, positioning solar energy as the third more important resource after the hydro and the wind-turbine energies, remind that the sun is an limitless source that specifically in this country produces an average of eight efficient daily hours per year. It is also a clean energy that helps to combat the climate change. For this and the big investment accomplished in the last years in the PV technology, the prices of this type of installations are becoming lower and making the exploitation a reality.



Graphic 1. Photovoltaic growth in Spain

The principal advantages of PV technologies are their versatility, the wide range of sizes and sites of installation resulting into proximity to electricity demand, the amount of energy obtained during the peak hours and the potential for further cost production.

Figure 1. Centralised Photovoltaic System

2. Description of solar energy

Solar energy is produced from the sun radiation that reaches the earth. The solar radiation reaching the earth can be for heat producing or also through the absorption of radiation to generate electric power, the one we are going to focus on.

There is more than enough solar irradiation available to satisfy the world's energy demand. On average, each square meter of land on Earth is exposed to enough sunlight to generate 1,700 kWh of energy every year using currently available technology. The total solar energy that reaches the Earth's surface could meet existing global energy needs 10,000 times over.

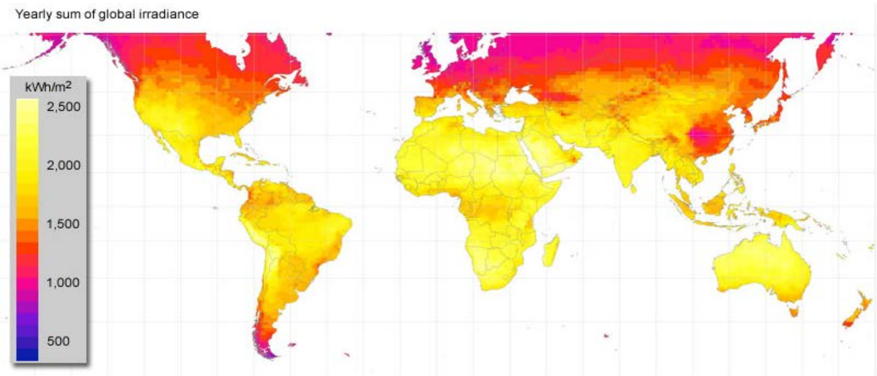


Figure 2. Yearly sum of global irradiance

2.1. Solar Radiation

Talking about the solar irradiance is necessary to mention that is subdivided in three different categories:

-Direct radiation: As it name suggest, this is the irradiation that comes direct from the sun that reaches the earth's surface

-Diffused radiation: While the direct radiation goes to the earth some of the particles stay in the atmosphere, it is quite important because in a sunny day it can provide around 19% of the solar irradiance and it becomes higher in a cloudy day.

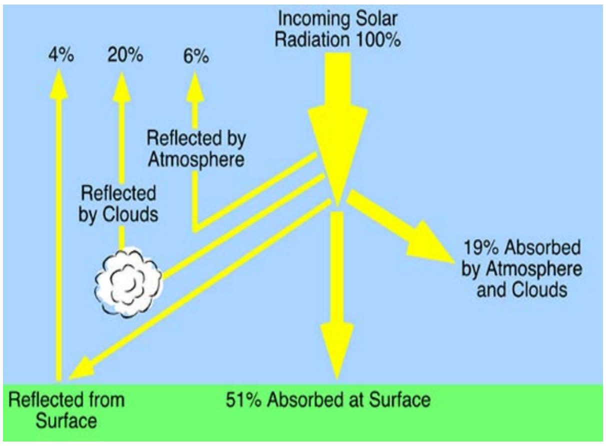


Figure 3. Incoming solar radiation

-Reflected radiation: is the radiation reflected from the clouds, the atmosphere and earth's surface

The sum of these three is what we called the global radiation

2.2. Motion and declination of the earth

As well, the solar radiation depends on several factors such as the atmospheric effects, the local variations like the pollution, the latitude of the location and the season of the year.

For the calculations we are going to perform later we need to take into account some of the next parameters:

The movement of the earth

The earth goes around the sun in an elliptical movement , once it completes a lap is what we consider one year, 365 days; during this movement the earth is in different positions in comparison to the sun.

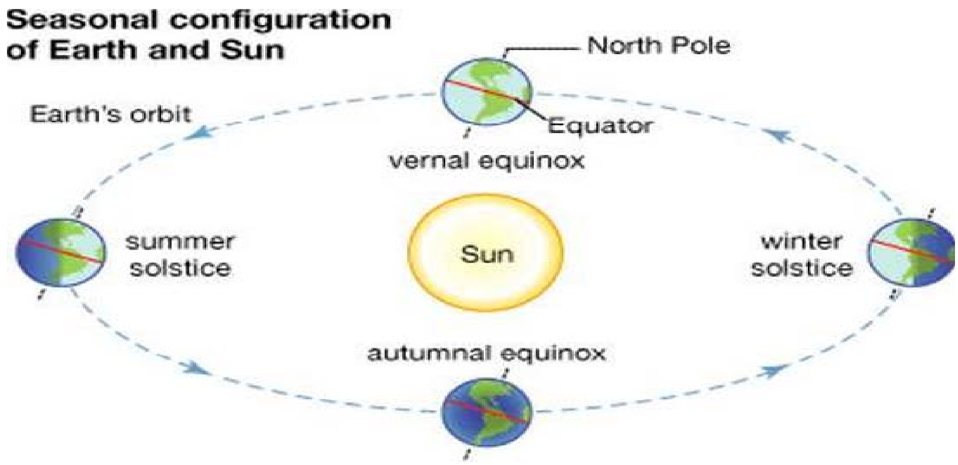


Figure 4. Seasonal configuration of the Earth

It is important to mention the two solstices, the winter solstice that begins the 21th of December where the north hemisphere is in farther position from the sun, this is assumed as less radiation that approaches the surface, and the summer solstice that begins approximately the 21th of June where the north hemisphere is closer and more sun energy reaches the surface; its opposite in the south hemisphere; usually in the equinoxes we have the same meteorological conditions.

<u>The declination of the earth</u>

The declination is the angular position of the sun at solar noon, with respect to the plane of the equator. Its value in degrees is given by Cooper's equation, this is useful to know which is going to be the inclination of our PV panels:

$$\delta = 23.45 \sin\left(2\pi \frac{284+n}{365}\right)$$

-where *n* is the day of year (*n* =1 for January 1, *n*= 32 for February 1…), Declination varies between -23.45° on December 21 and +23.45° on June 21.

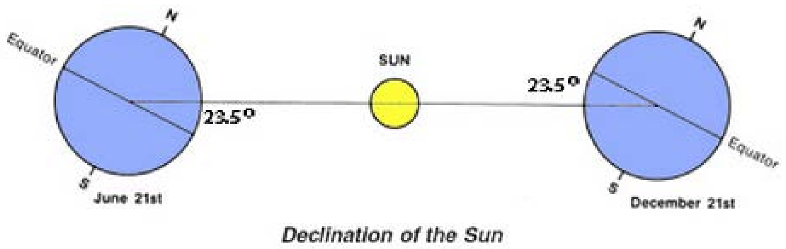


Figure 5. Declination of the Earth

3. PV Technology

Photovoltaic systems contain cells that convert sunlight into electricity. Inside each cell there are layers of a semi-conducting material. The fall of the light on the cell creates an electric field across the layers, causing electricity flow. The intensity of the light determines the amount of electrical power each cell generates.

·A photovoltaic system does not need bright sunlight in order to operate. It can also generate electricity on cloudy and rainy days from reflected sunlight, this is why we do not have to be afraid of the dependency of the sun

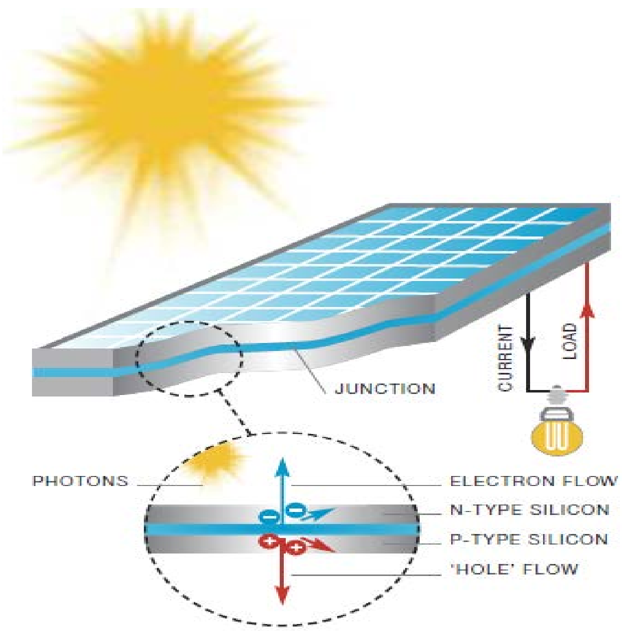


Figure 6. Solar panel

How photovoltaic cells produce electricity?

The generation of electric current happens inside the depletion zone of the P-N junction. The depletion region is the area around the PN junction where the electrons from the N-type silicon, have diffused into the holes of the P-type material. When a photon of light is absorbed by one of these atoms in the N-Type silicon it will dislodge an electron, creating a free electron and a hole. The free electron and hole has sufficient energy to jump out of the depletion zone.

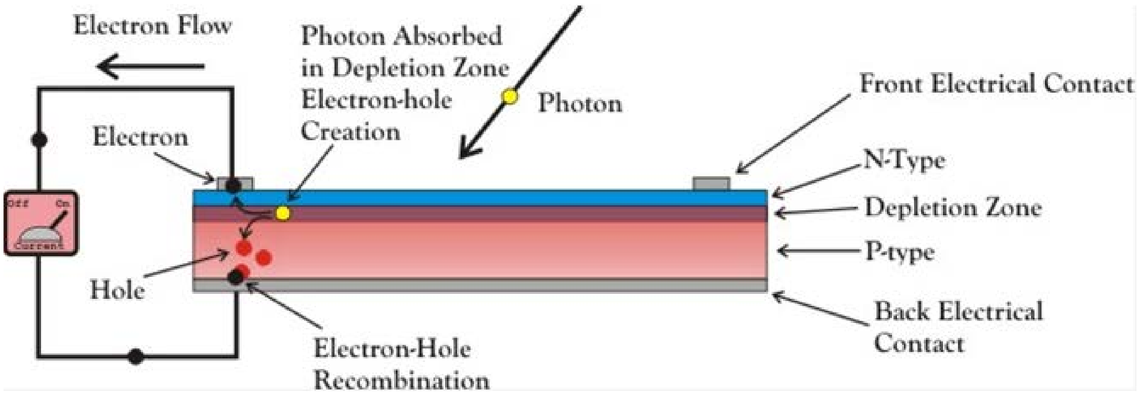


Figure 7. P-N junction

If a wire is connected from the cathode (N-type silicon) to the anode (P-type silicon) electrons will flow through the wire. The electron is attracted to the positive charge of the P-type material and travels through the external load creating a flow of electric current. The hole created by the dislodged electron is attracted to the negative charge of N-type material and migrates to the back electrical contact. As the electron enters the P-type silicon from the back electrical contact it combines with the hole restoring the electrical neutrality.

As the equivalent circuit of a solar cell p-n junction we have:

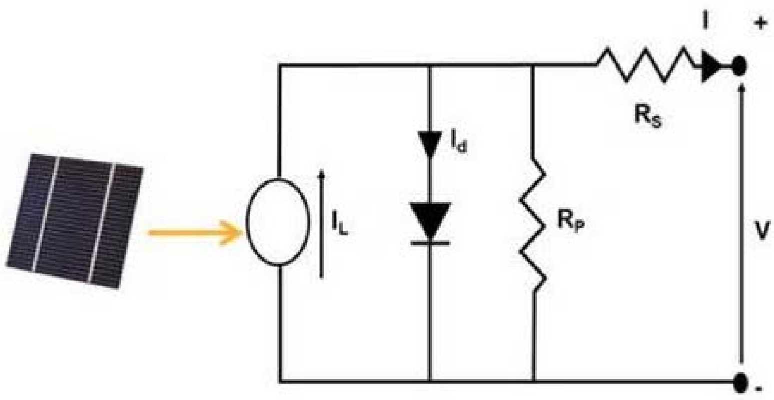
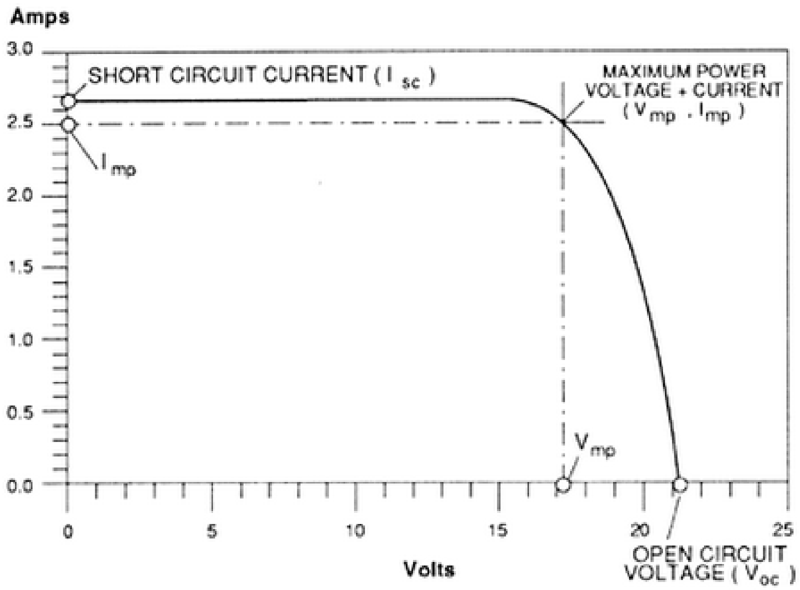


Figure 8. Equivalent circuit solar cell

In the previous circuit we can observe the parameters of a solar cell, the resistance in series R_S is due to the semiconductor material charge, the metallic contacts, the interconnections and the resistances between the metallic contacts and the semiconductor.

The parallel resistance or "shunt" R_p, is due to the non-ideal work of the junction p-n; the source of current I_L, represents the current generated from the solar irradiation and the diode represent the characteristic curve current-voltage I-V.



Graphic 2. Characteristic curve I-V

From the figure below we can mention that the Isc, the maximum current from a solar cell occurs when the voltage across the device is zero, and on the other hand that Voc in open circuit is the maximum voltage when the net current is zero.

Also the fill factor (FF) that shows us the quality of a solar cell: $$FF = \frac{V_{MP} I_{MP}}{V_{OC} I_{SC}}$$

We can say that if the Fill Factor > 0.7, the solar cell has a good quality

The energy it takes to make a solar power system is usually recouped by the energy costs saved over one to three years. Some new generation technologies can even recover the cost of the energy used to produce them in six months, depending on their location. PV systems have a typical life of at least 25 years, the efficiency decrease with the years but we can conclude that each panel generates many times more energy than its costs to install.

PV systems can be placed at the center of an energy generation network or used in the outskirts. Small PV generators can be spread through the network, connecting directly into the grid (on-grid systems). In areas that are too remote or expensive to connect to the grid, PV systems can be connected to batteries (off-grid systems).

4. On grid & off-grid systems

On-grid systems

When a PV system is connected to the local electricity network, any excess power that is generated can be fed back into the electricity grid. According to the policies of each country, the owner of the PV system is paid as the law says for the power generated by the local electricity provider.

In residential or commercial systems most of the solar PV systems are installed on homes and businesses in developed areas. By connecting to the local electricity network, owners can sell their excess power, feeding clean energy back into the grid. When solar energy is not available, electricity can be drawn from the grid. Solar systems generate direct current (DC) while most household appliances use alternating current (AC). An inverter is installed in the system to convert DC to AC.

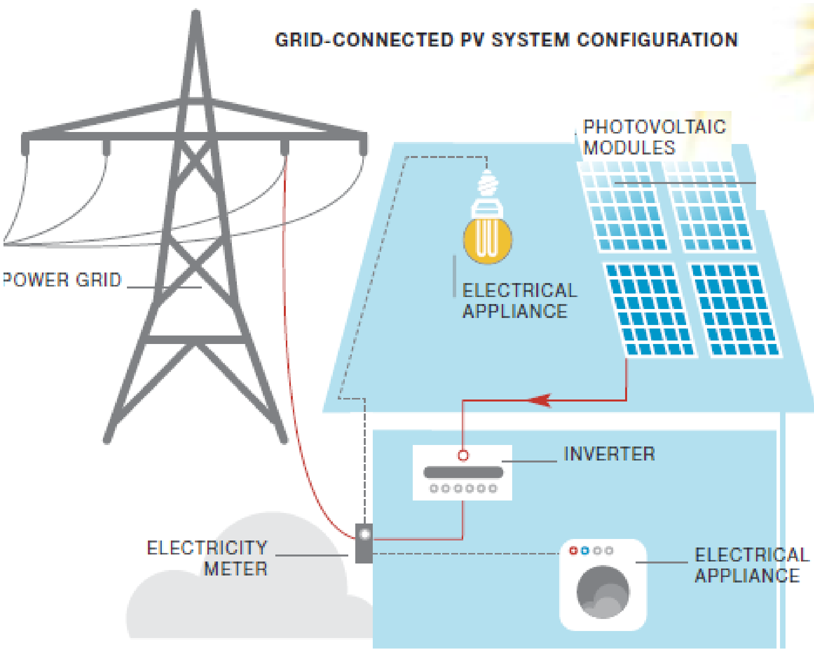


Figure 9. On-grid system

On Industrial and utility-scale power plants, large industrial PV systems can produce enormous quantities of electricity. These types of electricity generation plants can produce from many hundreds of kilowatts (kW) to several megawatts (MW). The solar panels for industrial systems are usually mounted on frames on the ground. However, they can also be installed on large industrial buildings such as warehouses, airport terminals or railway stations. The system can make double-use of an urban space and put electricity into the grid where intensive energy consumers are located.

Table 1. Applications of On-grid systems

Type of application	**Market segment**			
	Residential < 10 kWp*	Commercial 10kWp - 100kWp	Industrial 100kWp - 1MWp	Utility scale >1MWp
Ground-mounted			✓	✓
Roof-top	✓	✓	✓	
Integrated to facade/roof	✓	✓		

<u>Off-grid systems</u>

Off-grid PV systems have no connection to an electricity grid. An off-grid system is usually equipped with batteries, so power can still be used at night or after several days of low irradiation. An inverter is needed to convert the DC power generated into AC power for use in appliances. Most standalone PV systems fall into one of three main groups:

• Off-grid industrial applications

Off-grid industrial systems are used in remote areas to power repeater stations for mobile telephones (enabling communications), traffic signals, marine navigational aids, remote lighting, highway signs and water treatment plants among others. Both full PV and hybrid systems are used. Hybrid systems are powered by the Sun when it is available and by other fuel sources during the night and extended cloudy periods.

Off-grid industrial systems provide a cost-effective way to bring power to areas that are very remote from existing grids. The high cost of installing cabling makes off-grid solar power an economical choice.

• Off-grid systems for the electrification of rural areas

Typical off-grid installations bring electricity to remote areas or developing countries. They can be small home systems which cover a household's basic electricity needs, or larger solar mini-grids which provide enough power for several homes, a community or small business use.

• Consumer devices.

PV cells are now found in many everyday electrical appliances such as watches, calculators, toys, and battery chargers. Services such as water sprinklers, road signs, lighting and telephone boxes also often put on individual PV systems.

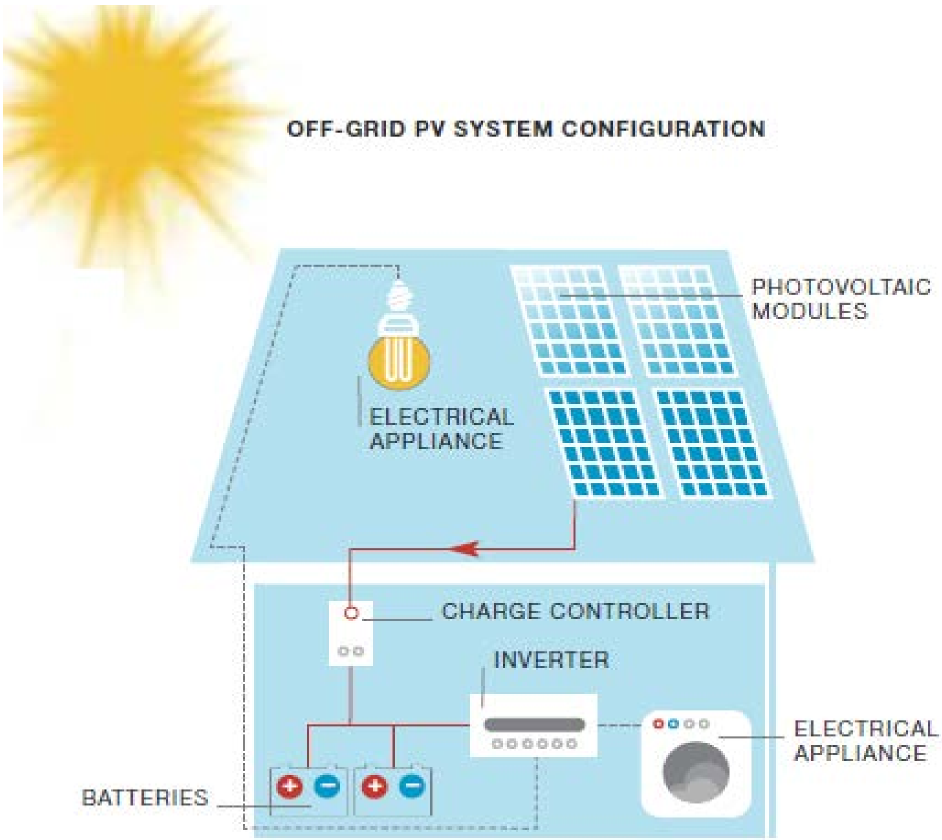


Figure 10. Off-grid system

5. Components of PV systems

PV modules are integrated into systems designed for specific applications. The components added to the module constitute the "balance of system" or BOS. Balance of system components can be classified in:

5.1. PV cells and modules

The solar cell is the basic unit of a PV system. PV cells are generally made from different materials that characterize its way of operation.

Cells are connected together to form larger units called modules. Thin sheets of Ethyl Vinyl Acetate (EVA) or Polyvinyl Butyral (PVB) are used to stick cells together and to provide weather protection. The modules are normally enclosed between a transparent cover (most of the times glass) and a weatherproof backing sheet (typically made from a thin polymer). Modules can be framed for extra mechanical strength and durability.

Modules can be connected to each other in series, called "strings", to increase the total voltage produced by the system with the same current or connected in "arrays", they are connected in parallel to increase the system current with the same voltage.

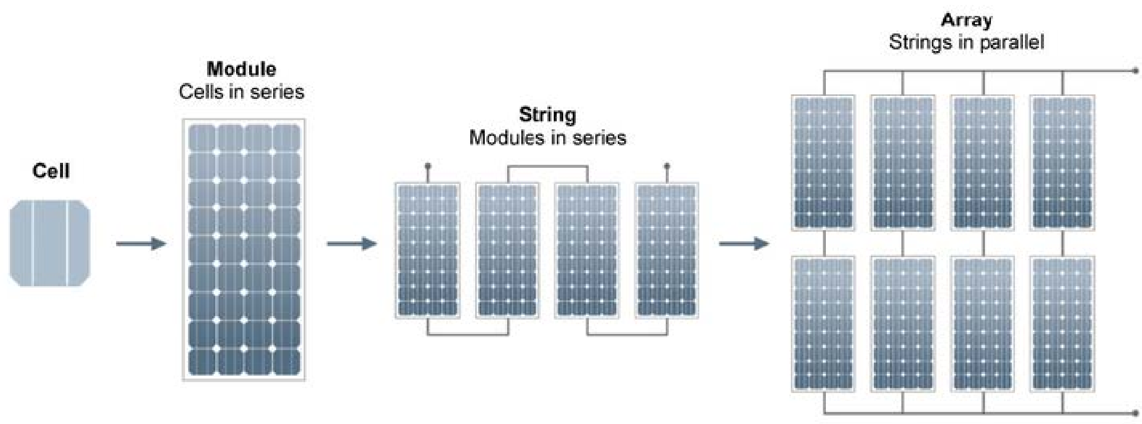


Figure 11. Series or Parallel connection of panels

The power generated by PV modules varies from a few watts (typically 20 to 60 W) up to 300 to 350 W depending on module size and the technology used. Low wattage modules are typically used for stand-alone applications where power demand is generally low.

Figure 12. PV panel

Also support structures are required in order to orient the PV modules toward the Sun.

5.2. Batteries

In an off-grid PV system, a battery is required as an energy storage device to share electricity even when there is no sunlight. The most common battery types are lead-calcium and lead-antimony. Nickel-cadmium batteries can also be used, in particular when the battery is subject to a wide range of external temperatures. Because of the variable nature of solar radiation, batteries must be able to go through many cycles of charge and discharge without damage. The amount of battery capacity that can be discharged without damaging the battery depends on the battery type.

Depending on site conditions, and on the presence of a backup generator, battery banks are sized to provide a period of system autonomy from a few days to a couple of weeks. Batteries are characterized by their voltage, which for most applications is a multiple of 12 V, and their capacity, expressed in Ampere-hours (Ah).

Figure 13. Stand-alone battery

The actual lifetime of a battery depends on how it is managed, optimizing the battery size is critical in obtaining good battery life, suitable system performance, and optimal system life-cycle costs. Unnecessary battery replacement is costly, particularly for remote applications.

5.3. Inverters and Rectifiers

Inverters convert the DC power generated by a PV module into AC power. This makes the system compatible with the electricity distribution network and most common electrical appliances. An inverter is essential for grid-connected PV systems. Inverters are offered in a wide range of power classes ranging from a few hundred to several kW.

An SMA inverter complements a pole-top solar PV array.
Photo courtesy of SMA Solar Technology AG

Figure 14. Inverter

Rectifiers (battery chargers), convert the AC current produced by a generator into the DC current needed to charge the batteries.

5.4. Charge regulators

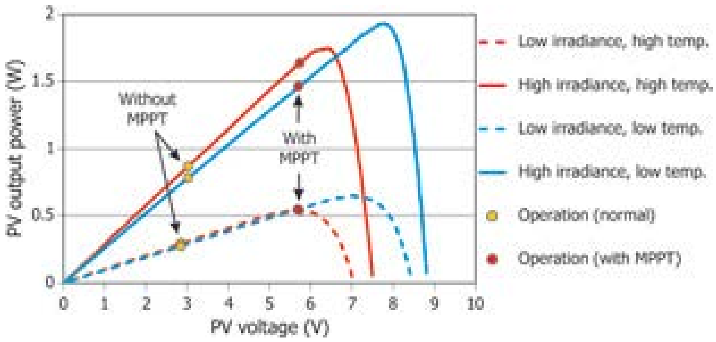
Several electronic devices are used to control and modify the electrical power produced by the photovoltaic array:

-Batteries are connected to the PV array via a charge regulator. The charge regulator protects the battery from overcharging or discharging. It can also provide information about the state of the system or enable metering and payment for the electricity used.

Figure 15. Charge regulator

-Maximum power point trackers (MPPT) that maintain the operating voltage of the array to a value that maximizes the array output.

Figure 16. MPPT



Graphic 3. Improvement of MPPT

6. Tracking systems

Tracking systems are very useful in order to catch more energy from the sun, they try to minimize the incident angle of the sun and then become more efficient, this systems need to be studied because in some cases the energy you need for tracking is higher than the one that you try to get.

Single-axis tracker VS Dual-axis tracker

-Single-axis trackers have a single degree of flexibility that serves as an axis of rotation. This is usually aligned along a North-South path, but it is possible to align them in any cardinal direction.

As its advantages we can say that single-axis trackers have lower cost, higher reliability and higher lifespan than the dual-axis; as disadvantages that they get lower energy output and they have fewer technological advances in comparison to dual-axis

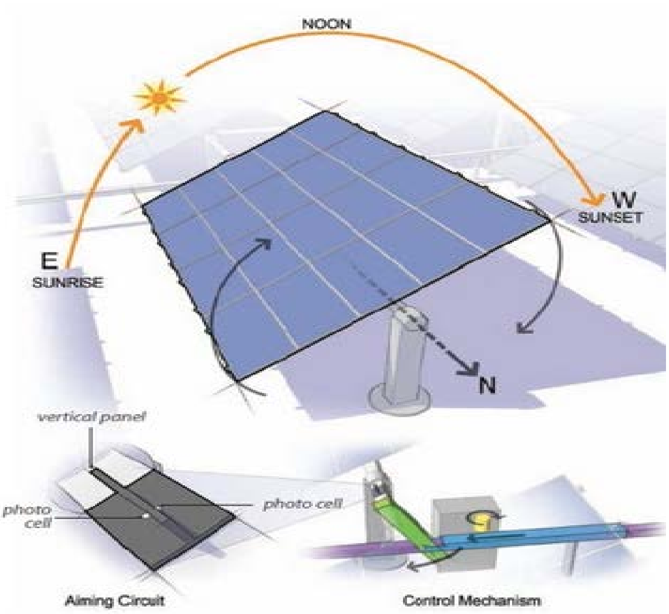


Figure 17. Single-axis tracker

On the other hand, dual-axis trackers allow for two degrees of flexibility, offering a wider range of motion. The primary and secondary axes work together to allow these trackers to point the solar panels at specific points in the sky.

As its advantages we can say that dual-axis trackers have a higher degree of flexibility and higher degree of accuracy in any direction point allowing it to get a higher output energy; as disadvantages that they have higher mechanical complexity, lower lifespan and reliability and that its performance is unreliable in cloudy days.

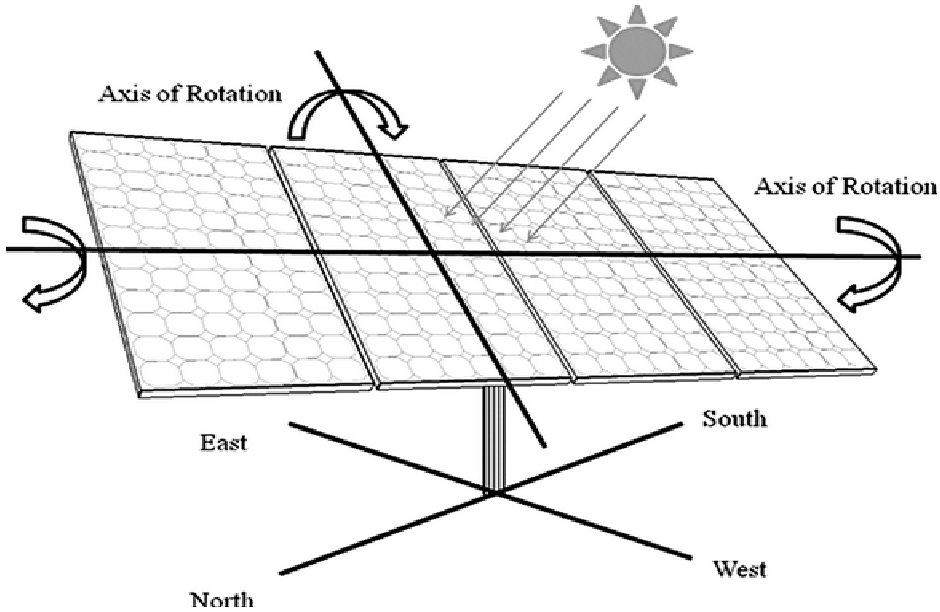


Figure 18. Dual-axis tracker

7. <u>Types of PV panels</u>

Solar cells science has vastly accelerated technological advances in the study of materials for solar cell and finding new concepts and processes for their production. Silicon as the main material for making solar cells absolutely dominates the market with a share of about 87% and predominantly in the technology of polycrystalline silicon but also in the technology of monocrystalline silicon; they are known as first generation of solar cells.

7.1 . <u>The solar cells of monocrystalline silicon (c-Si)</u>

It is made of a single crystal silicon, it production is expensive but the efficiency in this type of cells ranges from 16% to 22% and can generally be said that they are in wide commercial use and nothing to envy to the most efficient photovoltaic cells. For the production of monocrystalline silicon cells is required a pure semiconductor material. Monocrystalline rods are extracted from melted silicon and cut into thin plates (wafers). This method of preparation allows a relatively high degree of usability. The expected lifespan of these cells is typically 25-30 years, but of course as with all photovoltaic power output slightly degrades over the years.

Figure 19. Mono-C silicon cell

7.2 .<u>The solar cells of polycrystalline silicon (pc-Si)</u>

Production of these cells is economically efficient in comparison to single crystal due to the use of silicon wafers square that give more active module surface compared to monocrystalline wafers. The liquid silicon is poured into blocks which are cut into slabs. During solidification of the material to produce the crystal structure of various sizes, errors in the fabrication can occur, causing the solar cell has a slightly lower efficiency, the efficiency range of this type are from 14 - 18%. To increase the efficiency of the cell, the cell front surface may be covered with a transparent layer which reduces reflection of solar radiation. Life expectancy is between 20 and 25 years.

Figure 20. Poly-C silicon cell

The biggest technological disadvantage of this technology is the property that crystalline silicon is a semiconductor with an indirect band gap, which is why they need large thickness of the active layer in order to maximize the utilization of the energy of solar radiation. The new technology, which includes the use of silicon strip, has the advantage of being in such a manufacturing process avoiding the need of cutting wafers, which loses up to 50% of the material in the cutting process, that is why the possibility of the application of these technologies is highly expected in the near future.

7.3 Transparent solar cells

In recent times, especially in architecture, are beginning to use transparent solar cells. These cells will have particular importance in architecture and design in specific applications requiring transparency. Transparency cover make the light can easily come to the necessary places.

Figure 21. Transparent solar cell

Particularly flexible and transparent spherical modules, specifically and wired, can be integrated into elements of architecture or can be used in electronic devices.

7.4 Thin-film solar cells

The new thin-film technology known as second generation is applied to so-called semiconductors, its direct band gap and their thickness can be considerably less, which it means lower consumption of material and provides low cost and ability to produce large quantities of cells. Thin-film solar cells are made of several experimental semiconductor materials such as copper-indium-gallium-selenium (CIGS), copper-indium-diselenium (CIS) or cadmium telluride.

Thin Film modules are constructed by depositing extremely thin layers of photosensitive material on to a low-cost backing such as glass, stainless steel or plastic. Once the deposited material is attached to the backing, it is laser-cut into multiple thin cells. The performance of solar cells is very grateful because it gives them flexibility (compared to conventional rigid solar cells) that allows for widespread adoption.

However, their current effectiveness of 7 to 12% is significantly lower than conventional silicon solar cells.

The share of the thin-film technology in the market, despite considerable efforts, is around 6%. However, strong growth in the production of solar cells with crystalline silicon can cause an increase in prices and a shortage of raw silicon, so it is possible more thin-film technology in the future.

Four types of Thin Film modules are commercially available:

· Amorphous silicon (a-Si)

The semiconductor layer is only about 1 µm thick. Amorphous silicon can absorb more sunlight than c-Si structures. However, a lower flow of electrons is generated which leads to efficiencies that are currently in the range of 4 to 8%. With this technology the absorption material can be deposited onto very large substrates up to 5.7 m², reducing manufacturing costs. An increasing number of companies are developing light, flexible a-Si modules perfectly suitable for flat and curved industrial roofs.

-Thin Film solar panels of amorphous silicon tend to be flexible, not rigid like Poly or Monocristalline panels.

Figure 22. Thin Film solar panel

·Multi-junction thin silicon film (a-Si/µc-Si)

This consists of an a-Si cell with additional layers of a-Si and micro-crystalline silicon (µc-Si) applied onto the substrate. The µc-Si layer absorbs more light from the red and infrared part of the light spectrum. This increases efficiency by up to 10%. The thickness of the µc-Si layer is in the order of 3 µm, making the cells thicker but also more stable. The current maximum substrate size for this technology is 1.4 m², less than a-Si.

·Cadmium telluride (CdTe)

Cadmium telluride thin films cost less to manufacture and have a module efficiency of up to 11%. This makes it the most economical thin film technology currently available. The two main raw materials are cadmium and tellurium. Cadmium is a by a product of zinc mining. Tellurium is a by a product of copper processing. It is produced in far lower quantities than cadmium; despite these advantages, due to cadmium toxicity and suspected carcinogenic cadmium telluride is not widely used.

Availability in the long-term may depend on whether the copper industry can optimize extraction, refining and recycling yields.

·Copper, indium, gallium, diselenium / disulphide (CIGS) and copper, indium, diselenium/ disulphide (CIS)

CIGS and CIS offer the highest efficiencies of all Thin Film technologies. Efficiencies of 20% have been achieved in the laboratory, close to the levels achieved with c-Si cells. The manufacturing process is more complex and less standardized than for other types of cells. This tends to increase manufacturing costs. Current module efficiencies are in the range of 7 to 12%.

There are no long-term availability issues for selenium and gallium, Indium is available in limited quantities but they are no signs of an incoming shortage. While there is a lot of indium in tin and tungsten ores, extracting it could drive the prices higher. A number of industries compete for the indium resources: the liquid crystal display (LCD) industry currently accounts for 85% of demand. It is highly likely that indium prices will remain high in the coming years.

Table 2. Summary record efficiencies of Thin Film technologies

SUMMARY OF RECORD EFFICIENCIES OF THIN FILM TECHNOLOGIES

Thin Film technology	Record commercial module efficiency	Record Lab efficiency
a-Si	7.1%	10.4%
a-Si/μ-Si	10%	13.2%
CdTe	11.2%	16.5%
CIGS/CIS	12.1%	20.3%

So as summary of all types of technologies we have:

Table 3. Overview of Commercial PV module

OVERVIEW OF COMMERCIAL PV TECHNOLOGIES

Commercial Module Efficiency

Technology	Thin Film					Crystalline Silicon	
	(a-Si)	(CdTe)	CI(G)S	a-Si/μc-Si	Dye s. cells	Mono	Multi
Cell efficiency	4-8%	10-11%	7-12%	7-9%	2-4%	16-22%	14-18%
Module efficiency						13-19%	11-15%
Area needed per KW (for modules)	~15m²	~10m²	~10m²	~12m²		~7m²	~8m²

source: EPIA 2010. Photon international, March 2010, EPIA analysis. Efficiency based on Standard Test conditions.

7.5 Third generation photovoltaics

After more than 20 years of research and development, third generation solar devices are beginning to emerge in the marketplace.

Many of the new technologies are very promising. One exciting development is organic PV cells. These include organic PV solar cells (OPV) and the hybrid dye-sensitized solar cells (DSSC). Current cell efficiencies are about 6% for very small areas and below 4% for larger areas and the efficiencies achieved at the lab across a very small area are in the range of 8 to 12%. Commercial applications still have efficiency below 4%.

For both technologies, manufacturing costs is constantly decreasing. This is enabled by the use of the best manufacturing process and standard printing technologies. The major challenges for this sector are the low device efficiency and their instability in the long-term.

Third generation technologies that are beginning to reach the market are called "emerging" and can be classified as:

• Advanced inorganic Thin Films such as spherical CIS and Thin-Film polycrystalline silicon solar cells.

• Organic solar cells which include both fully organic and hybrid dye-sensitized solar cells.

• Thermo-photovoltaic (TPV) low band-gap cells which can be used in combined heat and power (CHP) systems.

Third generation PV products have a significant competitive advantage in consumer applications because of the substrate flexibility and ability to perform in the darkness or variable lighting conditions. Possible application areas include low-power consumer electronics and outdoor recreational applications.

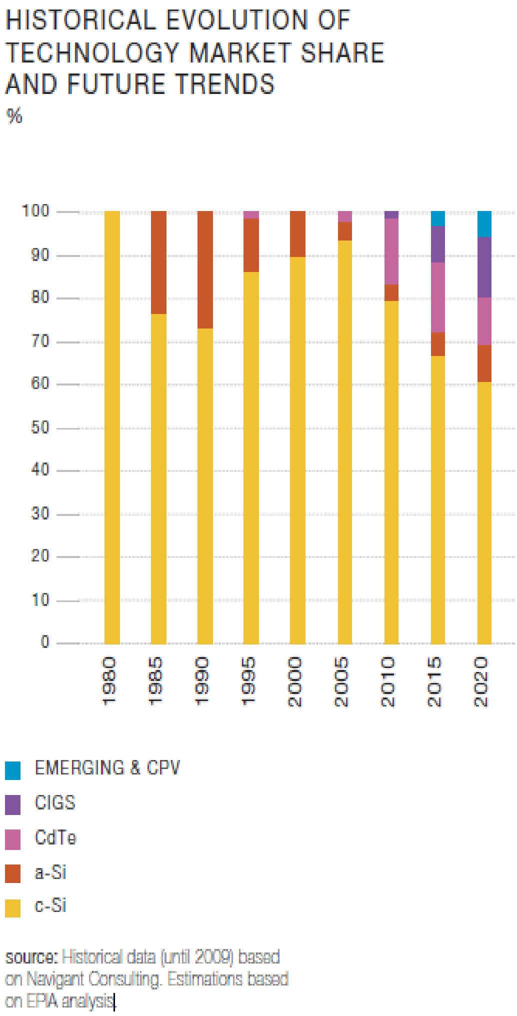
In addition to the emerging third generation PV technologies mentioned, a number of novel technologies are also under development:

• Active layers can be created by introducing quantum dots or nanotechnology particles.

• Tailoring the solar spectrum to wavelengths with maximum collection efficiency or increasing the absorption level of the solar cell. These adjustments can be applied to all existing solar cell technologies.

7.6 Historical and future evolution

Crystalline silicon technologies have dominated the market for the last 30 years. Amorphous silicon (a-Si) has been the technology most used for consumer applications due to its lower manufacturing cost while c-Si technologies have been used mainly in both stand-alone and on-grid systems.



Graphic 4. Historical evolution

With the c-Si technologies, mono and polycrystalline cells are produced in fairly equal proportion. However, polycrystalline cells are gaining market share. Amorphous silicon has been the preferred clear thin-film technology used over the last decade, its market share has decreased significantly compared to more advanced and competitive technologies. For example, CdTe has grown from a 2% market share in 2005 to 13% in 2012.

Technologies such as organics and dye-sensitized solar cells are beginning to enter the market. They are expected to achieve significant market share in the next few years, capturing around 5% of the market by 2020. EPIA (European Photovoltaic industrial association) expects that by 2020 silicon wafer-based technologies will account for about 61% of sales, while thin films will account for around 33%. Emerging technologies will account for the remaining 6%.

8. Additional information

8.1. Protection of photovoltaics systems

Each photovoltaic structure has a lightning protection system, earthing and surge arresters on the altern side; if the building has a solar photovoltaic modules, then the surge arresters have to have on the DC side.

Lightning protection system

Lightning occurs as a discharge of atmospheric electricity between clouds and the Earth, the voltage of one million volts, the strength of tens of thousands of amperes, in a short period of 1 to 100 milliseconds, with the rapid heating of the air up to 30 000 C, resulting in a thunderstorm.

Given that photovoltaic systems are usually installed on rooftops or large free surfaces, a lightning can easily happen. To be ensure of safe and continuous operation of a photovoltaic system, it is necessary to predict the overall protection from weather and induced surges.

The consequences of lightning on the photovoltaic modules will have repercussions on other electrical equipment and devices for the electrical connection between them.

So its needed a grounding system to let the current flow to the ground, it is possible with a ground wire with the smallest possible resistance to ease the current flow and its also needed a surge arrester, overvoltage can occur in the case of a direct lightning strike to the installation, surge arresters provide protection against atmospheric discharges in the network by equalizing the potentials.

8.2. Recycling

Photovoltaic modules contain materials that can be recycled and reused in new products. Industrial recycling processes exist for thin-film and silicon modules. Materials such as glass, aluminum and a number of semiconductor materials are still valuable after recycled. Recycling not only reduces the amount of waste, but also reduces the required amount of energy, and therefore the costs and the impact on the environment during manufacture of the module.

Photovoltaic modules are used to produce clean, renewable energy for over 25 years. As the first significant installations were in the early nineties, completely recycling will occur only in around 10 years. The PV industry is working to create sustainable energy solutions that take into account the environmental impact of all stages of the product lifecycle, from raw material source to the end of service life and recycling. Leading manufacturers accept responsibility and together voluntarily implement programs of return and recycling.

8.3. Maintenance of solar panels

One of the great things about solar energy is that the solar system has a very low maintenance. There are no moving parts, so if designed correctly, there are only a few things you need to do to keep getting out free solar energy:

- Dusty solar panels will decrease your solar output. If you live in a low-dust climate with occasional rain, you may need to go on your roof and wipe off those panels with some mild water, don't use any strong detergents. Depending on your roof and solar configuration, you might even be able to do this with an extended mop, extended squeegee, and a garden hose without getting on to the roof.
- If you live in dusty climates you may need to clean your system more often to get the most power.
- Also be aware of bird droppings, leaves, or other debris that might fall on your roof. Make a schedule to take a visual look at your solar system to make sure it's clear.

8.4. Solar monitoring devices

Another way to make sure you're getting the most solar potential out of your PV system is through a monitoring systems and service. For a monthly fee or a flat up front cost, you can monitor how your system is performing.

- Your system is expected to produce a certain amount of power during each month. A solar monitoring system can tell you if your system is off line or if it's not performing as expected and run diagnostic programs.
- Solar monitoring systems can also be educational, showing you how much power, CO_2 or money you have saved.
- Monitoring systems are usually an extra expense, whether as a monthly service or purchased up front. While not essential, they do make troubleshooting and system performance easier to see.

9. REAL PROJECT OF A SUSTAINABLE HOUSE IN SPAIN

9.1 Solar Project in Almuñecar, Spain.

Generally speaking, it is important to design a photovoltaic system that determines its entire lifetime. Photovoltaics systems must be carefully designed and they must be taken into account all influencing factors in order to achieve the best characteristics of the available resources and reduce the possible systemic losses to achieve a return on your investment.

The designer must take into account the efficiency and the average specific price (€/kW) for different production technology modules, as well as all electrical parameters and costs of installation and maintenance.

Figure 23. House PV panels rooftop integrated

Location of the project

The house for the project will be located in the south of Spain, in Almuñecar (Granada), in the roof of a residential house to optimize the needed area.

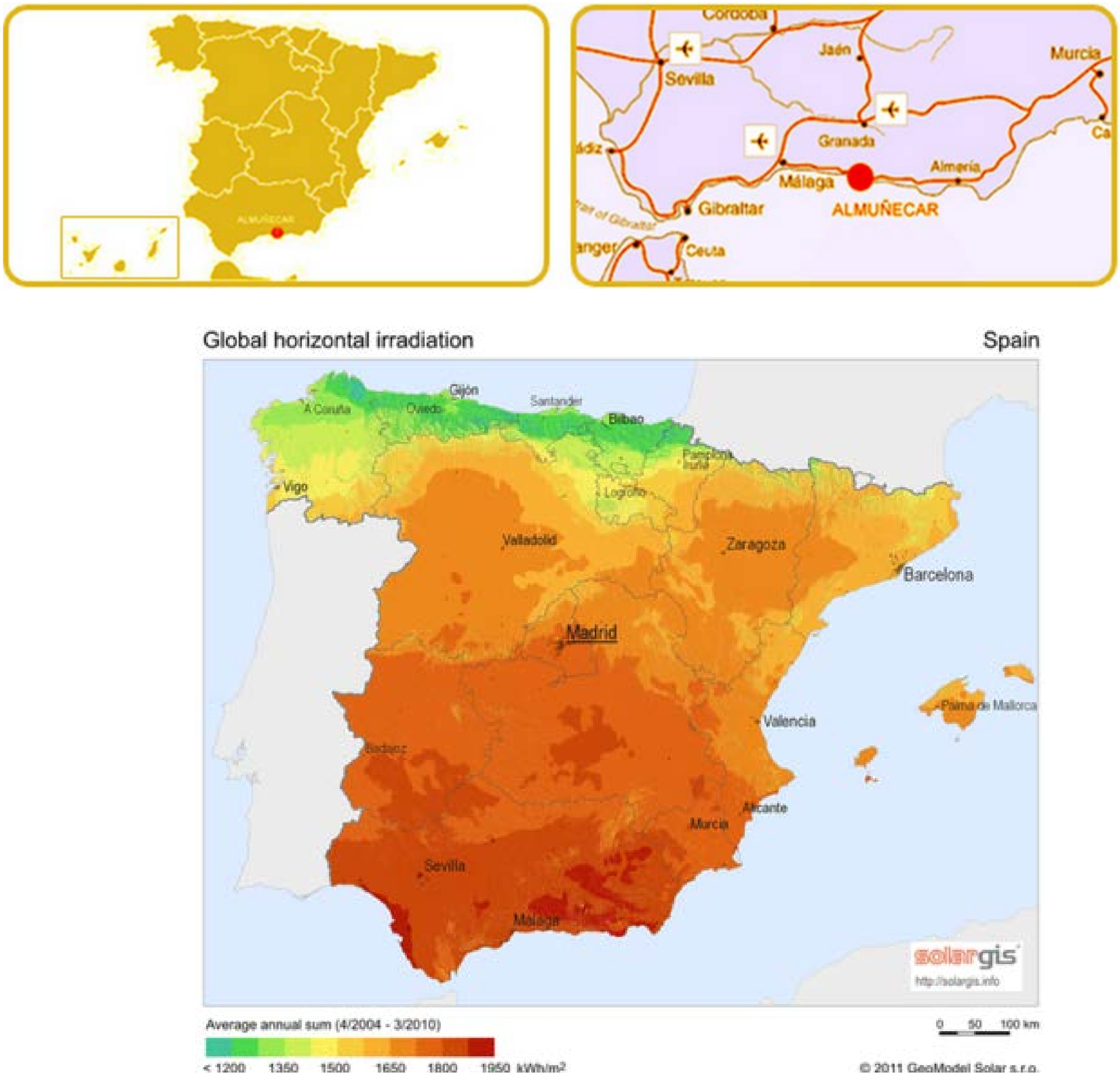


Figure 24. Location of the project

As we can observe it is a very good location with a big potential for this type of installation; geographic coordinates:

Latitude : 36.7167° N

Longitude : -3.6833° E

9.2. Power required

The project will take part in this location and it will consist in a photovoltaic installation design for a residential house for four people.

We assume that house is approximately going to consume:

Appliance	Power [W]	Energy [kWh]
Freezer	170	500
Refrigerator	80	200
Dish washer	1000	262
Washing machine	1500	257,4
Iron	2200	213
Vaccum cleaner	1000	39
Hair dryer	1200	124,4
Toaster	1500	19,1
Electric owen	1200	168,5
DVD player	20	0,5
HIFI 1	200	156
TV 1	100	110
PC	200	189,5
Lights different types		1200
Other home appliances		400
TOTAL	10370	3839,4

Here is important to mention the difference between kW and kWh:

One kW is the unit of measure the power (W), when we see the specifications of an electric device, the W tell us how much power its needed for make it work.

One kWh is a unit to measure the consumption of electricity, and it is defined to see the used power in a period of time.

So for a medium-big residence for five person that want some home appliances working together we need a contracted power of 5,75 kW (normalized), this means that we can't connect at the same time the home appliances that overcome this amount because the fuses will go down and as seen before 3839,4 kWh annual average consume depending on how many devices we require, due to the performance of the regulator, inverter and battery its estimated some losses around 6%, for what we need to at least achieve:

3839, 4 kWh/0.94 = 4084, 468 kWh ≈ 4100 kWh

9.3. Calculations

First of all we need to do some off-grid calculations to see the characteristics of the system, we can do this by searching on the website an off-grid calculator and introduce the parametres of our house.

The best way to get the maximum output of PV panels is with a guided monitoring system that follows the sun direction, but in this case we are going to create an installation with fixed panels, that are easier and more economic, oriented to the south and changing the inclination depending the time period.

9.3.1. PVGIS system

We are going to use the information of PVGIS system (Photovoltaic Geographical Information System), which provides an estimate of the production of electricity from photovoltaic systems on the basis of maps in Europe, Africa and Southeast Asia, where there are hundreds of meteorological monitoring stations which directly or indirectly measures the solar radiation.

In PVGIS system is necessary to enter the exact coordinates of the location of the system and enter some basic information about the photovoltaic system to let PVGIS be able to accurately estimate the meteorological parameters.

We can select two different types, Classic PVGIS database, that is based on measurements on the ground, while the Climate - SAF PVGIS is based on satellite estimations; for this particular case we are going to select Climate – SAF PVGIS, this region of Spain has subtropical climate and we are going to take the calculations in a very optimist way, so we run the program at:

http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php

It appears a window like this, we select the location:

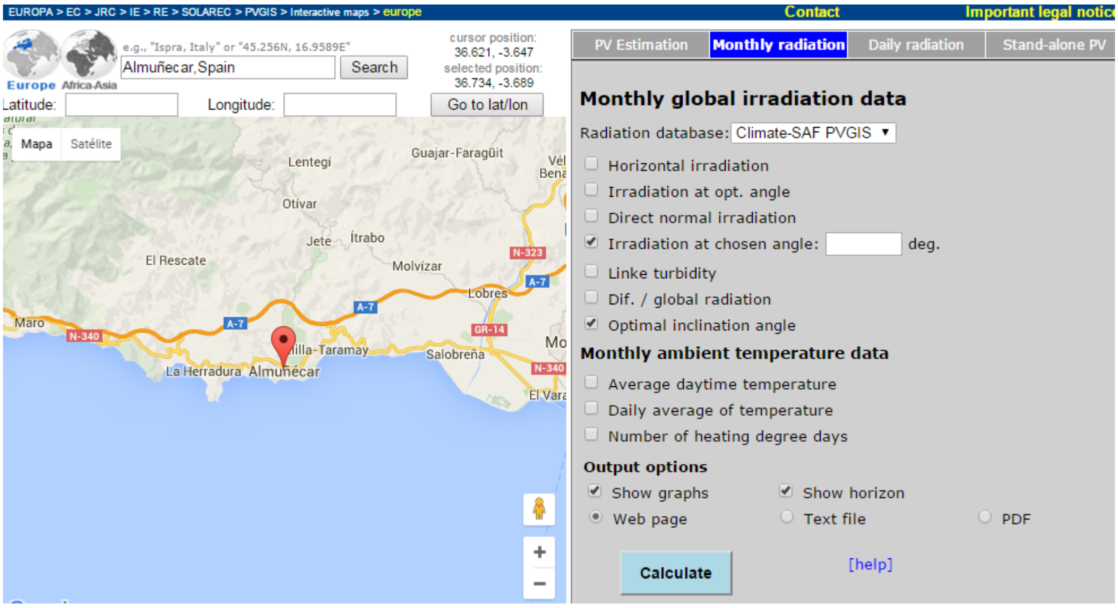
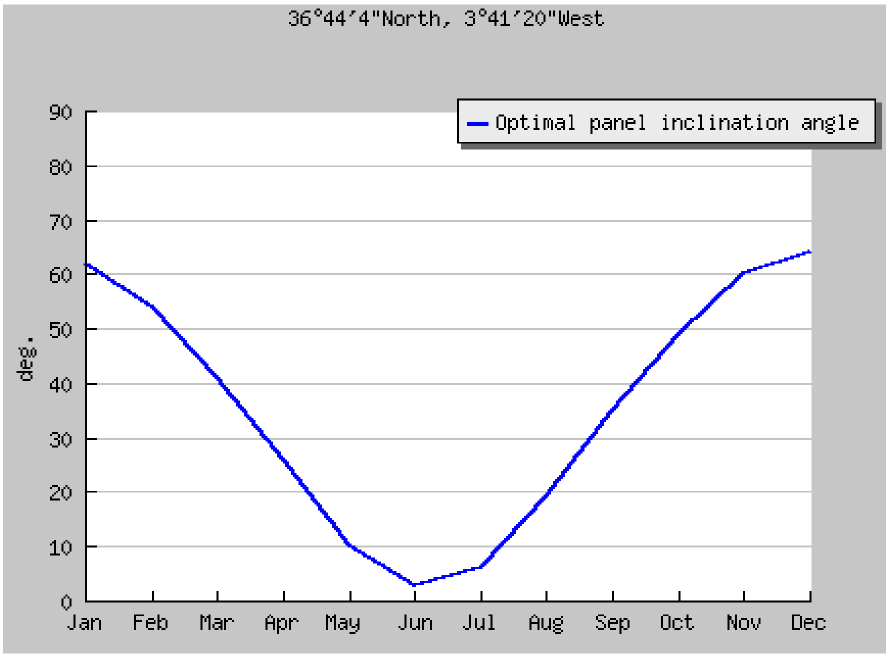


Figure 25. PVGIS

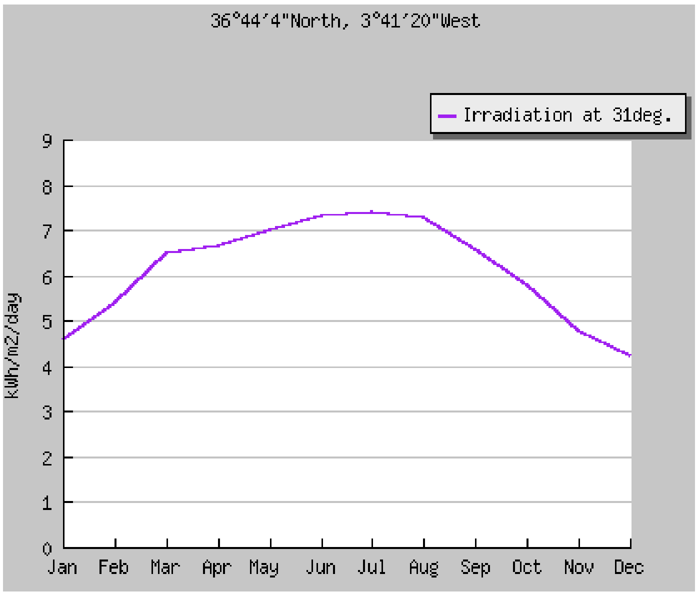
First we calculate the optimal inclination angle for the PV panel along the year:



Graphic 5. Optimal inclination angle during the year

So approximately the best inclination angle is 31°, respect to the ground and as we said before, fixed and facing directly to the south; it will be installed the way we can adjust the inclination angle depending the period of the year to be optimal; one axis tracker.

Now we have the optimal inclination angle we calculate the montly irradiation:

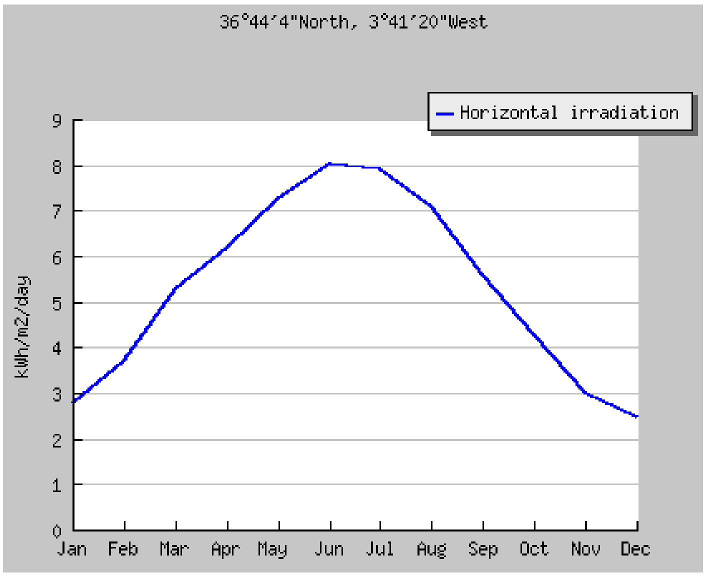


Graphic 6. Monthly titled radiation

Month	H(31)
Jan	4570
Feb	5380
Mar	6500
Apr	6640
May	6990
Jun	7310
Jul	7390
Aug	7280
Sep	6560
Oct	5790
Nov	4770
Dec	4240
Year	6120

Table 4. Monthly titled radiation

We will also need the horizontal solar irradiation:



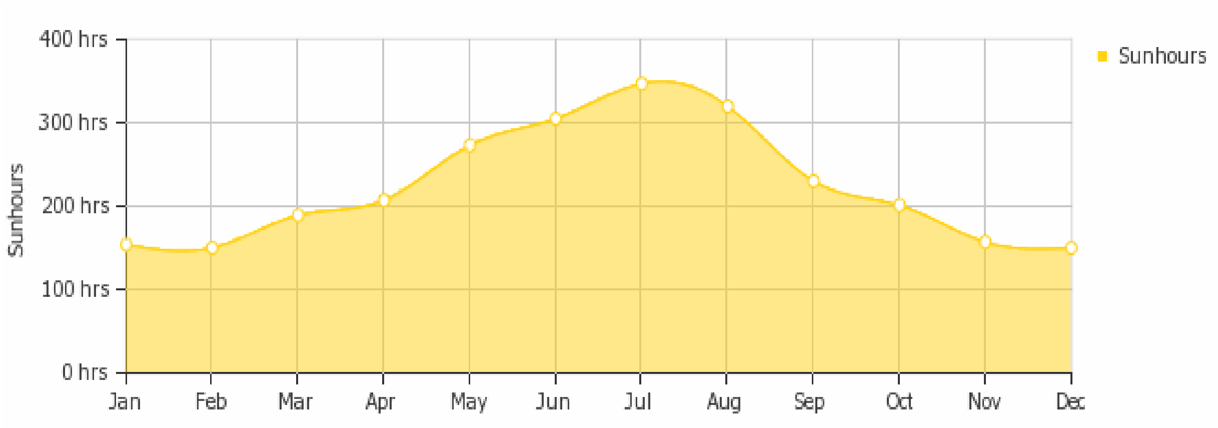
Graphic 7. Monthly horizontal irradiation

Month	H_h
Jan	2780
Feb	3710
Mar	5280
Apr	6200
May	7280
Jun	8030
Jul	7920
Aug	7080
Sep	5570
Oct	4260
Nov	3000
Dec	2470
Year	5310

Table 5. Monthly horizontal radiation

*H measured in Wh/m^2

And the daily hours of sun we are going to have:



Graphic 8. Daily hours of sun

Based on this graphic we expect to have around 7.31 hours of sun per day as an average for the year, 5.25 hours per day in the winter period and 9.37 hours per day in the summer period.

9.3.2. Photovoltaic modules

After we have this information we proceed with the calculations, remember that we have an estimated consumption of 4100 kWh per year.

4100kWh (yearly) = 341.66kWh (monthly) = 11232.876 Wh

Or what is the same, we can also measure the consumption in amperes per hour:

Q_{AH} = Wh(daily)/V_{BAT}= 11232.876 Wh/ 48 V =234.018 Ah

We assume that in principle our battery is of 48 V because we expect around 5kW of consumption.

So for calculating the number of PV modules we are going to need to supply the enough energy to the system we base on the next formula:

$$N_{mód} = \frac{C_{ed}}{P_{MP} \cdot HSP_{crit} \cdot PR}$$

Where:

- C_{ed} is the total daily expected consumption in Wh, 11233 Wh (daily)
- P_{MP} is the peak power of the module, in our case we are thinking about 310 W
- HSP_{crit} is the solar irradiation in kWh/m^2 of the critic month, December, $4.24 kWh/m^2$
- PR is the performance coefficient due to temperature, shadows, dirt…we assume 0.9%

Solving the formula with the previous parameters we got:

N_{MOD}= 9.495 so we are going to need 10 PV modules.

The photovoltaic panels will be placed on the roof of the house to minimize the required area, the ones we are going to use are of the company China Sunergy and the model is CSUN310-72P with 310 W of power, we need a total of 10 panels, connected in parallel.

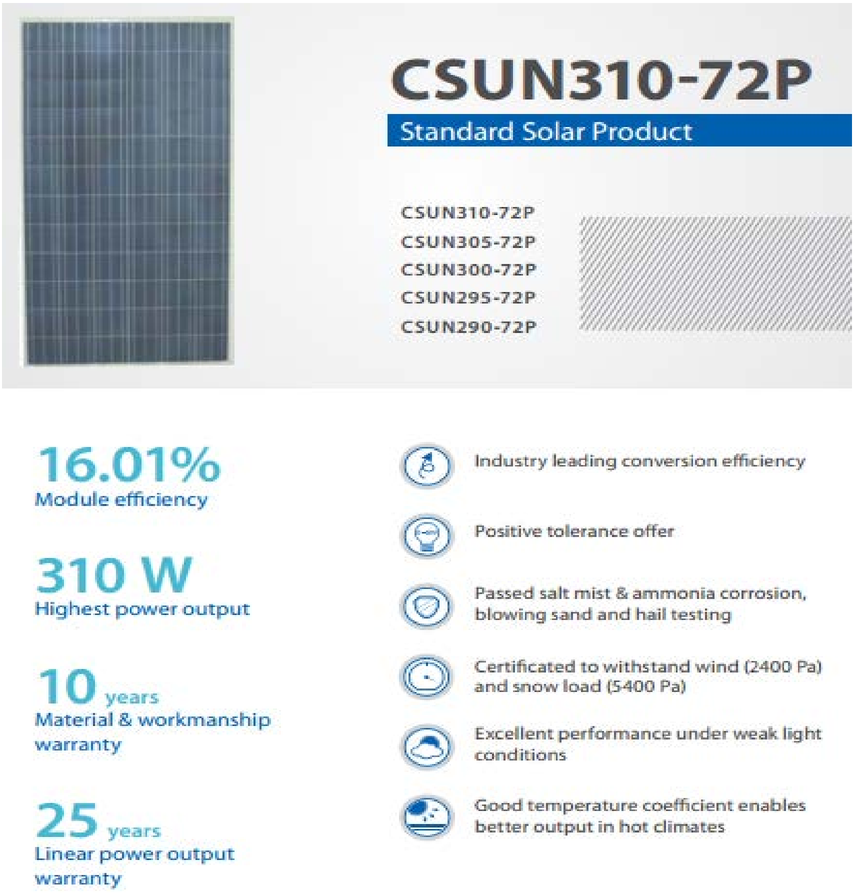
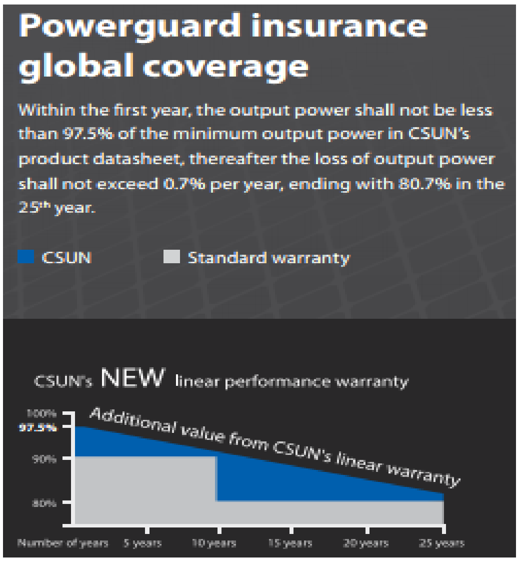


Figure 26. CSUN310-72P characteristics

As further information we can consider:

Electrical characteristics at Standard Test Conditions (STC)

Module	CSUN 310-72P
Maximum Power - Pmpp (W)	310
Positive power tolerance	0~3%
Open Circuit Voltage - Voc (V)	44.8
Short Circuit Current - Isc (A)	9.04
Maximum Power Voltage - Vmpp (V)	36.1
Maximum Power Current - Impp (A)	8.58
Module efficiency	16.01%



Temperature Characteristics

Voltage Temperature Coefficient	-0.292%/K
Current Temperature Coefficient	+0.045%/K
Power Temperature Coefficient	-0.408%/K

Mechanical Characteristics

Dimensions	1956 × 990 × 50 mm
Weight	22.3 kg
Frame	Anodized aluminum profile
Front glass	White toughened safety glass, 3.2 mm
Cell Encapsulation	EVA (Ethylene-Vinyl-Acetate)
Back Sheet	Composite film
Cells	6 × 12 pieces polycrystalline solar cells series strings (156 × 156 mm)

Taking into account the previous specifications and despising the depth because it is insignificant, the total area we are going to need for the 10 panels is a rectangle 2x5 panels with a total of 3.912m of height and 4.95m of width.

The price per panel is 310 € so for the total amount of 10 would be 3100€.

To see the complete datasheet click the link below:

Datasheet : http://pdf.wholesalesolar.com/module%20pdf%20folder/Astronergy-ASM6612P-315-SolarPanel-Specifications.pdf?_ga=1.172930147.1776276319.1453122868

9.3.3. The Inverter

The inverter converts the DC output of the solar panels into AC current for the correct consumption of electricity of the home devices.

To calculate the characteristics of our inverter we need:

-The total voltage output:

V_{MP}= 36.1 V (as they are connected in parallel this is the total output)

-The total current output:

I_{MP}=8.58 A but because of the 10 panels we expect an I_{tot}= 8.58 · 10 = 85.8 A

-The power:

We have to estimate how much is the maximum instant power, for this particular case we can say we expect 2800 W depending on the home appliances, also we need a security margin of 25 %.

P= 1.25 · 2800W = 3500 W

Once we have done the calculations we estimate that the best inverter is the "MAGNUM MS4448PAE inverter"

Figure 27. MAGNUM MS4448PAE inverter

Some of its characteristics are 4000 W of power, 266 A as maximum current, input voltage of 48 V as our battery and it provides a sinusoidal wave that it is better for most of the electric devices.

This inverter has a price of 1997, 78 €

To see the complete datasheet click the link below:

Datasheet: http://pdf.wholesalesolar.com/inverter%20pdf%20folder/MS-PAE-Sheet.pdf?_ga=1.171422816.1776276319.1453122868

9.3.4. The battery

For the calculations of the battery what is it important to know is:

·Maximum depth of discharge (seasonal) = 0.75 (75%)

·Maximum depth of discharge (daily) = 0.25 (25%)

·Number of autonomy days, n = 5

·Q_{Ah} (calculated before) = 234.018 Ah

There are two ways of knowing the nominal capacity of our battery, it should be chosen the one more restrictive:

-$C_N = Q_{Ah}/0.25$ = 936.072 Ah

- $C_N = Q_{Ah} * n/0.75$ = 1560.12 Ah

We stay with the last value, taking into account this specifications we will use the "48 V 2000Ah Tubular Gel Battery Bank", with a capacity of 96kWh and with a life service of around 25 years.

For further information:

Datasheet: http://www.aussiebatteries.com.au/off-grid-solar/battery-banks/48v-2000ah-tubular-gel-battery-bank

Figure 28. Tubular gel battery bank

The price of this battery is 22,557.64€, this is the most expensive device of the installation

9.3.5. <u>The charge regulator</u>

To dimension this devices it is important to know the maximum current, calculated before the expected current is of 85.8 A, but giving a security margin of 30 %, the expected current will be 111.54 A; with this characteristics the optimal regulator will be the regulator “Somalia 48V 120A Solar system charge controller with DC load”

Datasheet: http://www.alibaba.com/product-detail/Somalia-48V-120A-Solar-system-charge_60412183727.html?spm=a2700.7724857.29.12.ZcAdCu&s=p

-The price of the regulator is 630 €

Figure 29. Charge regulator

9.3.6. Total Inversion

After describing all the elements of the system we continue doing an economic study to have an estimation of the inversion we need to run the installation:

Table 6. Prices

Device	Price
PV panels	3.100 €
Inverter	1.998 €
Battery	22.558 €
Charge regulator	630 €
TOTAL	28.286 €

9.4. RETSCREEN

After having sized the parameters of the systems we proceed to run RETSCREEN 4 for do the calculations and viability of the project.

First of all we give name to the project and we select the field of study, photovoltaic off-grid and select the location of the project.

Once we have done this, due to that Almuñecar doesn't appear in the database of Retscreen we proceed to introduce the calculations of the irradiation we obtained before with the PVGIS manually.

	Unit	Climate data location	Project location
Latitude	°N	37,2	37,2
Longitude	°E	-3,8	-3,8
Elevation	m	570	570
Heating design temperature	°C	-2,2	
Cooling design temperature	°C	36,0	
Earth temperature amplitude	°C	23,7	

Month		Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
		°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January		5,9	76,7%	2,78	95,4	1,4	6,3	375	0
February		7,9	71,9%	3,71	95,3	1,8	8,6	283	0
March		11,1	65,9%	5,28	95,0	2,2	13,2	214	34
April		13,4	62,9%	6,20	94,7	2,5	17,2	138	102
May		17,4	59,0%	7,28	94,8	2,5	22,9	19	229
June		22,6	51,4%	8,03	94,9	2,5	29,7	0	378
July		25,6	45,9%	7,92	94,9	2,4	32,8	0	484
August		24,9	49,3%	7,08	94,9	2,2	31,4	0	462
September		21,0	58,3%	5,57	95,0	2,0	25,5	0	330
October		15,6	69,6%	4,26	95,0	1,7	18,5	74	174
November		10,2	77,4%	3,00	95,0	1,5	11,8	234	6
December		6,9	79,9%	2,50	95,3	1,4	7,7	344	0
Annual		15,3	64,0%	5,31	95,0	2,0	18,9	1.681	2.199
Measured at	m					10,0	0,0		

After this we proceed to complete the parameters:

*We are going to introduce the prices/cost in € instead of $.

Power project

Base case power system

Grid type		Off-grid
Technology		Grid electricity
Fuel rate	$/kWh	0,144
Capacity	kW	3,10
Annual O&M cost	$	1.980
Electricity rate - base case	$/kWh	0,627
Total electricity cost	$	2.570

Load characteristics

⦿ Method 1
○ Method 2

	Unit	Base case	Proposed case
Electricity - daily - DC	kWh		
Electricity - daily - AC	kWh	11,233	11,233
Intermittent resource-load correlation			Zero

☐ **Percent of month used**

		Base case	Proposed case	Energy saved
Electricity - annual - DC	MWh	0,000	0,000	
Electricity - annual - AC	MWh	4,100	4,100	0%
Peak load - annual	kW		2,80	

Base case power system:

-Technology : Grid electricity

-Price of the electricity in Spain : 0.144 €/kW

-Capacity of the installation: 310 W ·10 Panels = 3.10 kW

-Annual Operating & Maintenance cost (Around 7% of the total inversion) =1980 €

Load characteristics:

-Electricity-daily-AC = 11.233 kWh as expected what we need daily, with this number it is calculated the annual expected consumption 4.1 MWh

-Peak load-annual = As explained before we expect as a maximum of 2.8 kW of peak demand

Proposed case power system				
				Incremental initial costs
Inverter				
Capacity	kW	4,0	Peak load - annual - AC	$ 1.998
Efficiency	%	96%		
Miscellaneous losses	%	4%		
Battery				
Days of autonomy	d	5,0		
Voltage	V	48,0		
Efficiency	%	96%		
Maximum depth of discharge	%	80%		
Charge controller efficiency	%	9500%		
Temperature control method		Ambient		
Average battery temperature derating	%	3,3%		
Capacity	Ah	2.000	621	
Battery	kWh	96		$ 22.557
Technology		Photovoltaic		
Resource assessment				
Solar tracking mode		Fixed		
Slope	°	31,0		
Azimuth	°			

☑ Show data

Inverter:

-Capacity = 4 kW

-Initial costs = 1998€

-Efficiency = 96%

-Miscellaneous loses = 4%

Battery:

-Days of autonomy = 5

-Voltage = 48 V

-Efficiency = 96%

-Maximum depth charge = 75 %

-Charge controller efficiency = 95%

-Capacity = 2000 Ah (1814 Ah due to efficiencies)

-Incremental costs = 22557€

Resource assessment :

-Solar tracking mode = one-axis

-Slope = 31° (Inclination)

☑ Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity delivered to load MWh
January	2,78	5,52	0,38
February	3,71	6,34	0,34
March	5,28	8,47	0,38
April	6,20	8,41	0,37
May	7,28	9,66	0,38
June	8,03	10,34	0,37
July	7,92	10,46	0,38
August	7,08	10,18	0,38
September	5,57	8,30	0,37
October	4,26	7,50	0,38
November	3,00	5,72	0,37
December	2,50	5,19	0,38
Annual	**5,31**	**8,02**	**4,45**

Annual solar radiation - horizontal	MWh/m²	1,94
Annual solar radiation - tilted	MWh/m²	2,93

In the table before we can see the daily solar horizontal and titled radiation, the program give us its annual average and what is more important, we can observe the total electricity delivered to the load, as mentioned before we expect to need around 4.1 MWh and with the parameters established we obtain that we are going to reach 4.45 MWh annually, 108.5% over the expected, so we did good calculations.

Photovoltaic				
Type		poly-Si		
Power capacity	kW	3,10	110,7%	$ 3.100
Manufacturer		China Sunergy		
Model		poly-Si - CSUN310-72P	10 unit(s)	
Efficiency	%	16,0%		
Nominal operating cell temperature	°C	45		
Temperature coefficient	% / °C	0,40%		
Solar collector area	m²	19,4		
Control method		Maximum power point tracker		
Miscellaneous losses	%	0,0%		
Summary				
Capacity factor	%	31,5%		
Electricity delivered to load	MWh	4,45	108,5%	
Peak load power system				
Technology		Grid electricity		
Fuel rate	$/kWh	0,144		
Charger efficiency	%	98,0%		
Suggested capacity	kW	2,8		
Capacity	kW	4	125,0%	
Electricity delivered to load	MWh	0,0	0,0%	

Here we introduced the parameters of the PV panels, as well as that we are using Maximum Power Point Tracker (MPPT) but the program does not take into account the inversion for this device and the characteristics of the peak load system, having 4 kW of capacity give as a margin of 25% for any higher peak load than the expected of 2.8 kW.

Emission Analysis

Base case electricity system (Baseline)		GHG emission factor (excl. T&D)	T&D losses	GHG emission factor
Country - region	Fuel type	tCO2/MWh	%	tCO2/MWh
Spain	All types	0,238		0,238

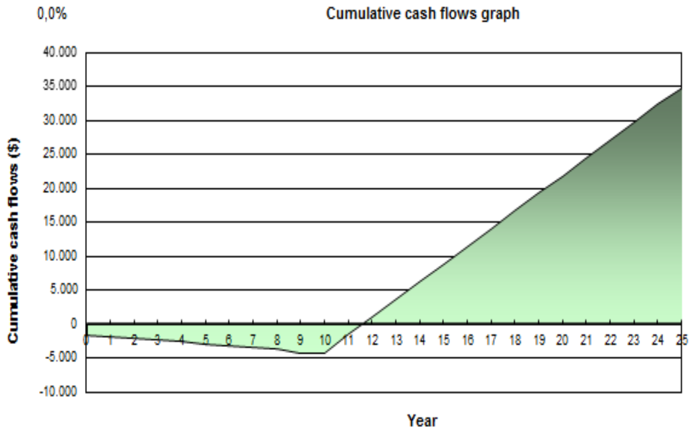
GHG emission					
Base case	tCO2	1,0			
Proposed case	tCO2	0,0			
Gross annual GHG emission reduction	tCO2	1,0			
GHG credits transaction fee	%	7,0%			
Net annual GHG emission reduction	tCO2	0,9	is equivalent to	390	Litres of gasoline not consumed

Looking into the emission analysis we find out that the building of our installation is equivalent to save an amount of 390 liters of gasoline.

The GHG credit transaction fee is based on the European indicators, that shows that it was 7 % for Spain in 2012.

Financial Analysis

Financial parameters			
Inflation rate	%	0,1%	
Project life	yr	25	
Debt ratio	%	94%	
Debt interest rate	%	1,21%	
Debt term	yr	10	
Initial costs			
Power system	$	27.655	97,8%
Other	$	631	2,2%
Total initial costs	$	28.286	100,0%
Incentives and grants	$		0,0%
Annual costs and debt payments			
O&M (savings) costs	$		
Fuel cost - proposed case	$	0	
Debt payments - 10 yrs	$	2.836	
Other	$		
Total annual costs	$	2.836	
Annual savings and income			
Fuel cost - base case	$	2.570	
Other	$		
Total annual savings and income	$	2.570	
Financial viability			
Pre-tax IRR - equity	%	16,9%	
Pre-tax IRR - assets	%	1,4%	
Simple payback	yr	11,0	
Equity payback	yr	11,6	



Here it is what we consider a preliminary financial analysis of the project, searching on the website we find and introduce the financial parameters in the program, also in this window we introduce the extra cost of the charge regulator.

As a result we get the cumulative cash flow graph, where we can observe the economic evolution of the project, it is shown that 11.6 years after the project begins we start saving money.

Conclusion

As a conclusion for this document we may point the high potential of the solar radiation energy, the main question is how to keep improving its extraction; photovoltaic systems currently do not have a high degree of efficiency and they are not able to compete with other conventional energy sources, but it also should be taken into account that their technically exploitable potential is not negligible, it is far higher than other renewable energy sources such as biomass, water power and wind power. The current effectiveness of conversion technologies is generally lower than 20%, but it is assumed to increase significantly in the near future.

To obtain the maximum possible electricity production is important to do a research about the type of installation we want to install, such as which is the optimal panel I want to introduce, the inverter, the battery, dual or single axis tracker and also take into account the meteorological conditions, because it does not has sense to put a PV installation in a place with no solar potential; if we realize a good study selecting an optimal location and the pertinent photovoltaic devices we can reach the point of being totally electrically independent.

In this particular document we performed an estimation of the photovoltaic resources that are needed to create a self-sustainable house for four people (electrically speaking), after doing a research of the costs of this installation and with the help of RETSCREEN we can say that this project is in a first view viable (it is a very rough estimation), so if we are capable of doing this investment, besides of using a clean and renewable energy, in a few year we will be saving money.

However, conversion technologies have not yet reached commercial mass production and are dependent on state subsidies; anyway the experts prevails an optimistic view of the potential of photovoltaic industry, comparing it with the industry of mobile phones during the nineties, and it is projected to long-term that the photovoltaic industry will be much higher.

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SUMMARY

"The small photovoltaic installation for a self-sustainable house"

In this document is presented the basics of the solar energy and the physical principles of PV technology, as well as the necessary components of a photovoltaic installation and the types of solar cells available, such as mono or poly crystalline cells, thin films, emerging technologies and also their development and future challenges; in addition to this an analysis of the technologies for obtain an optimal output of energy is realized and the operating and maintenance details are commented.

The meteorological conditions are analyzed; It is also performed a techno-economical and viability analysis for a photovoltaic installation in the south of Spain, selecting the suitable devices for its proper work and with the help of RETSCREEN the cash flow of the investment for the installation is performed.